SUBJECT: Determination of Depth of Lunar Surface Layer Using LEM Landing Radar - Case 150

DATE: November 17, 1964

FROM: J. L. Marshall, Jr.

SUMMARY

Bellcomm has been asked to "examine the use of a second radar to measure the depth of the surface layer by comparison with the X-band radar". Following are some factors considered significant in evaluating this proposal:

1. The success of this scheme depends upon the lunar surface model chosen. If the system design were based upon an incorrect model, information on the surface layer would be either obscure or totally absent. If the surface layer can be assumed homogeneous, one method of attack would be to select two frequencies such that one reflects primarily from the top and the other primarily from the bottom, and then compare the ranges measured at the two frequencies. Theoretically an accurate determination of the range to the top of the surface could be made because of the sharp transition in properties between space and the surface layer. Unfortunately this may not be the case at the bottom of the surface layer, where the nature of the transition zone is completely unknown.

2. Present data, though not conclusive, indicates that the "dust" layer would probably be transparent to X-band radiation from the landing radar.

3. The frequency chosen for the second radar should be one that would definitely be reflected from the top of the surface. The best choice would probably be in the visible light range, i.e., a laser could be used.

4. One significant source of error would be the range accuracy of the X-band landing radar, which is presently specified as 1% or 5 feet, whichever is greater. Thus, even at low altitudes, and considering all other error sources negligible, the uncertainty in measuring the depth of the surface layer would be ±5 feet. Any significant improvement in the accuracy of the X-band landing radar would be accompanied by an increase in weight.

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It has been concluded that the proposed scheme does not appear practical for use as a LEM landing aid because of the uncertainties involved.

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MEMORANDUM FOR FILE

INTRODUCTION

Bellcomm has been asked to "examine the use of a second radar to measure the depth of the surface layer by comparison with the X-band radar".

There are two distinct aspects to the problem: (1) the physical properties of the lunar surface, and (2) the requirements imposed upon the LEM hardware. This memorandum briefly summarizes some pertinent facts and assumptions regarding these physical properties,* and considers their effects upon the LEM hardware. These considerations lead to the conclusion that this scheme is not practical as a LEM landing aid.

PHYSICAL PROPERTIES OF THE LUNAR SURFACE

It has been suggested that an additional radar be provided for the LEM so that range measurements made at two different frequencies could be compared to give a measure of the depth of the "dust" layer on the lunar surface. It is assumed that the intent is to use this information primarily as a landing aid to help certify a landing area for the LEM. An alternative use, more experimental in nature, would be an attempt to attain more information on the characteristics of the lunar surface. In this case, the localized measurements made by the LEM radars would be analyzed and compared with those already made by radars on the Earth. The data would presumably be recorded for future analysis when adequate time and computation facilities would be available. This latter approach is not considered in this memorandum.

The practicality of developing an operational system to measure the depth of the surface layer clearly depends upon the present knowledge of the lunar surface and the accuracies

*All statements in this memorandum concerning the physical properties of the lunar surface are based upon conversations with W. B. Thompson. A more detailed discussion of these properties is contained in a separate Memorandum for File by W. B. Thompson (in preparation).

required. For example, consider an ideal situation in which the lunar surface consists of two distinct surfaces with different, but known characteristics. Then, the frequencies of the two radars might be chosen such that one would penetrate the top layer and be reflected from the lower surface, while the other would be reflected from the top surface. The ranges determined from the two measurements could be compared, and, if the velocity of propagation within the surface layer were known, the depth of this layer could be determined.

However, there is no assurance that the lunar surface model considered above is correct. There is evidence that suggests such a model, but this is by no means conclusive. Thus, a system implemented utilizing this model would yield erroneous results if the surface were of a different form, such as a smoothly varying composition rather than one with an abrupt change. It should also be noted that the model would necessarily be based upon radar measurements made from the Earth, which would provide information on the gross overall characteristics of the surface. It is questionable whether such a model would apply equally well to all local areas of concern on the moon. In addition, the limitations in our present knowledge of the velocity of propagation within the surface layer would lead to an uncertainty of ±10% in determining the depth of this layer.

It is clear that the two frequencies should be chosen such that one would penetrate the surface "dust" but the other would not. It is assumed that one of the frequencies chosen would be at X-band, since the present landing radar operates in this range. Unfortunately, data now available does not indicate conclusively whether X-band radiation actually penetrates the surface dust. If it is assumed that it does, then an obvious choice for the other frequency would be in the visible light range, since light would be reflected from the surface. Perhaps a more nearly optimum combination would be light and a frequency lower than X-band. However, if it is considered that the development of the present landing radar should not be disturbed, the choice of light and X-band would be better than X-band and a lower frequency.

ACCURACY

A summary of the error sources that have been considered is contained in Table 1. Specific numbers could not be associated with some of these sources because of the limited knowledge of the lunar surface characteristics. Lack of knowledge upon which to base a lunar surface model was discussed in the previous section. The success of the scheme depends entirely upon the model chosen. Radar measurements from the Earth have not shown

but in order to obtain a narrower beam, the antenna would have to be made larger, and therefore heavier. Further, if it were determined that a lower frequency than X-band is required, the weight of the landing radar would increase just to maintain the present accuracy requirements.*

A study of size, weight, accuracy, etc. for lasers is beyond the scope of this memorandum. However, the laser accuracy would probably be better than that of the X-band radar because of the much narrower beam. It should be noted that in 1962 Grumman proposed the use of a laser as part of the radar subsystem to provide slant range data, but such a system was not implemented.

Measurements by the radar and laser represent averages over the areas illuminated by their beams. If the "dust" layer were non-uniform and there were irregularities in the surface and/or subsurface, the depth indication would be based upon the average ranges. If the beamwidths were equal, it would be important that they both illuminate the same area. However, if a laser and the X-band radar were used, the laser beam would be very small compared with the X-band beam. Then the depth measurement would vary depending upon where the laser beam pointed within the radar beam. Alignment requirements could pose difficult mounting problems, and it could be quite difficult to provide a mounting area on the LEM with satisfactory visibility.

OTHER CONSIDERATIONS

If a laser, or another radar, were added to the LEM, some means of comparing the information from them must be provided. It would probably be best to utilize the LEM guidance computer (LGC) for this, since it would be desirable for the laser to serve also as a backup to the landing radar. It is expected that the addition of this interface would have a greater effect upon LGC schedules than upon the LGC hardware.

A two frequency system using a laser would be ineffective at altitudes low enough for the LEM descent engine to cause a dust cloud, since such a cloud would reflect the laser beam.

SUMMARY AND CONCLUSIONS

Following is a summary of the factors considered important in evaluating the proposal:

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*See "Choice of Operating Frequency Band for the LEM Landing Radar - Case 215", Memorandum for File by A. G. Weygand, dated September 9, 1964.

Attachment
Table 1

Copy to
Messrs. J. J. Hibbert
J. A. Hornbeck
B. T. Howard
D. B. James
B. Kaskey
C. M. Klingman
C. R. Moster
I. M. Ross
E. N. Shipley
R. V. Sperry
T. H. Thompson
W. B. Thompson
J. M. West
A. G. Weygand

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TABLE 1

SUMMARY OF ERROR SOURCES

Imperfect lunar surface model	
a. Selection of model, e.g., distinct layers vs. gradual transition in inhomogeneous material	Unknown
b. Propagation velocity uncertainty within surface layer (assuming a model with a distinct layer and abrupt transition to a more compact subsurface layer)	10%
X-band landing radar range accuracy	1% or 5 feet
Laser range accuracy	probably smaller than landing radar
Difference in beamwidths of laser and landing radar	Unknown
Irregularities of surface and surface layer within radar beamwidth	Unknown

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